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# USING ANIMATED GRAPHICS ON AIRCRAFT NAVIGATION DISPLAYS; PROS AND CONS

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An advantage of animations is improving an operator's ability to reconstruct information space. However, research also shows there can be disadvantages to the use of animation including the mismatch of the operations concepts of speed or motion of the task and the perceptions of the animation. An exploratory study was conducted to determine pilot opinions of whether animation would help them to respond to a route change instructions from Air Traffic Control rapidly and with high levels of interpretation accuracy. Many pilots indicated that animation would support their performance, but that animation should be optional and pilots should be able to control the speed of the animation.

Pilots communicate with air traffic control (ATC) through datalink communications (DataComm) as well as voice communications, and must perform successful interpretation of navigation clearances for the safe flight. Aircraft depict the current flight plan to pilots via their navigation displays (NDs). When pilots receive navigation clearances, pilots use the ND to support their interpretation of the clearance compared to the current flight plan. If pilots receive complex route clearances, they must perform complicated spatial reasoning. This may impose considerable pilot workload and misinterpretation of the clearance is possible (Gallimore, Kiss, Munoz, Oh, Crory, Ward, Green, Shingledecker, & Tsang, 2013). Even delayed interpretation can cause renegotiation with ATC. To support pilot clearance interpretation, novel forms of complex routing presentations need to be explored. Animated graphics may support understanding of route clearances.

The purpose of this exploratory study was to obtain pilot subjective feedback on the possible use of animation to present route and reroute information on the ND.

## Background

Animation is a form of computerized graphics used to convey dynamic situation information. Humans have a tendency to perform inferences of causality, which implies that people may have an internal animation process in their mind (Hegarty, 1992). Researchers have shown that some animation applications have improved operator performance. Roscoe and Jensen (1981) showed that animated graphics of visual guidance and flight-prediction enhanced pilots' accuracy of curved approaches to airport runways. According to Payne, Chesworth and Hill (1992), a short animation to instruct how to use a computer program was effective. The properties of animation for performance improvement using animation have been investigated. Bartram (1997) theorized preattentive and interpretative properties of motion made animation a useful scheme to express complex information. Bederson and Boltman (1999) found that animation enhances operator's ability of reconstructing spatial information space without any degradation on task time. According to Tversky, Morrison and Betrancourt (2002), animated graphics can represent more information than static graphics or text, and animation enhanced the interactivity between operators and the display interface. An advantage of animation was shown for extracting incidental information in education applications (Rieber, 1991). In classes using computer-assisted education to teach complex and sophisticated concepts, animations were beneficial (Thatcher, 2006; Lin, 2011).

Researchers have also shown that animations were a perceptually problematic form, and their efficacy was questionable (Morrison, Tversky, & Betrancourt, 2000; Tversky et al., 2002). Bartram (1997) found that some operators were unable to correctly perceive the animation speed and this led them to dislike animations. Tversky et al. (2002) asserted that excessively complex and fast visual effects in animations used to convey the information of complex systems inhibited operators' ability to apprehend the information. If a given event is not inherently integrated into sequences of discrete steps in nature but a continuous event, the expressed animation may not deliver the right information (Morrison et al., 2000; Lee, Klippel, & Tappe, 2003). Researchers also found that animated displays are not effective because there were mismatches between the attributes of motion and the nature of the task at hand (Rieber, 1991; Morrison et al., 2000). Many animated displays often highlighted task-irrelevant features

(Lee et al., 2003). Morrison and Tversky (2001) showed both static graphics and animated graphics were preferred to text to convey spatial information, but the static graphics and animations did not show any significant difference in the spatial reasoning performance. Lee and Klippel (2005) found another pitfall of animated graphics for a spatial route finding application. Operators paid attention to the critical landmarks and non-critical landmarks equally while the animation was played (Lee & Klippel, 2005).

Researchers have investigated ways to make animations more effective. There are design guidelines for animation; "the animation process should be represented according to the user's mental model and system entities, and the user should be allowed to control the animation duration and replay it" (Stasko, 1993). Other examples of proposed principles for reducing the cognitive load caused by animations are as follows; animations should be segmented into small sections (Ayres & Paas, 2007), provide operators the capability of controlling the presentation (Ayres & Paas, 2007; Hegarty, 2011), signal the key information (Ayres & Paas, 2007), limit extraneous factors (Ayres & Paas, 2007), use of hybrid approaches of static and animated graphics in applications; animations accompanied with static diagrams are an effective alternative to animated-only instructional procedures in some applications (Lee et al., 2003; Ayres & Paas, 2007). Another proposed strategy for effective animations was adding attention cueing such as arrows, color, or luminance contrast (spotlight effect) to create instructional animations by integrating a series of static representations (de Koning, Tabbers, Rikers, and Paas, 2009; Amadieu, Marine, and Laimay, 2011). The fundamental idea of cueing is similar to the concept to designing salient features into static representations. Cues should be used to draw user attention to the key attributes illustrated in the animation within the animation time period. de Koning et al. (2009) provided a framework for cueing design; guiding operator attention to facilitate the selection and extraction of essential information, emphasizing the main idea of instruction and organization, and making clear the relations between and within elements to foster integration. These attention cues enhanced operator comprehension both of cued information and uncued information (de Koning, Tabbers, Rikers & Paas; 2007). de Koning et al. (2009) suggested developing new cues that work in animations rather than simply reusing the cues which had been effective for static representations for the same task.

The use of attention cueing described by Amadieu et al. (2011) and de Koning et al. (2009) were used to design animation into a ND with the idea of supporting pilot interpretation of DataComm clearances. This first study was developed to obtain pilot feedback related to the use of animation.

## **Evaluation**

### **Prototype**

A prototype and test system of an ND that presented both current route and cleared routes with animation was developed. Figure 1 presents a sample screenshot of the ND. The test system included a current flight plan overview section, a text (DataComm) clearance section, and a ND section. A magenta line was used to indicate the original flight path as it is currently used on NDs. A white triangle at the bottom of the display indicates ownship. Graphic symbols were also used to indicate ground stations such as VORs, airports, and waypoints. Novel graphics were created to present the cleared route (see Figure 2). Each cue was designed to guide the operators' attention to specific locations and detailed operation indications (de Koning et al., 2009; Amadieu et al., 2011). They included the following:

- Dotted green line: new flight path of ownship.
- Caret green line: new heading of ownship.
- Text label: new altitude of ownship.
- Ownship changes color based vertical clearance information, and moves along routes.

When activated, the ownship symbol moves along the new path indicated by the DataComm clearance. The test program was developed using JAVA language under NetBeans SDK version 7.0 and presented to pilots on a monitor. An external numeric keypad was used to start the animations. Half the route clearances were incorrect scenarios with respect to the flight plan and the other scenarios were correct.

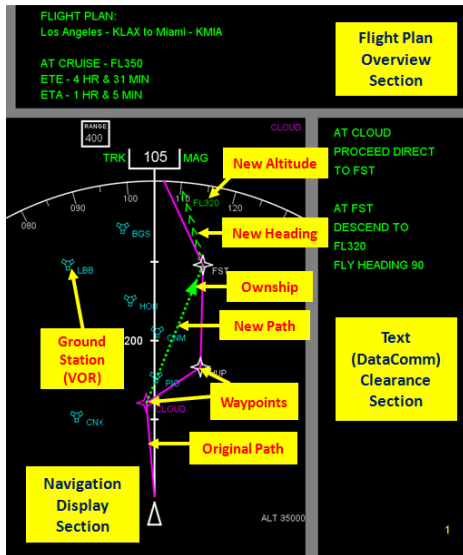


Figure 1. Setting of Test Program.

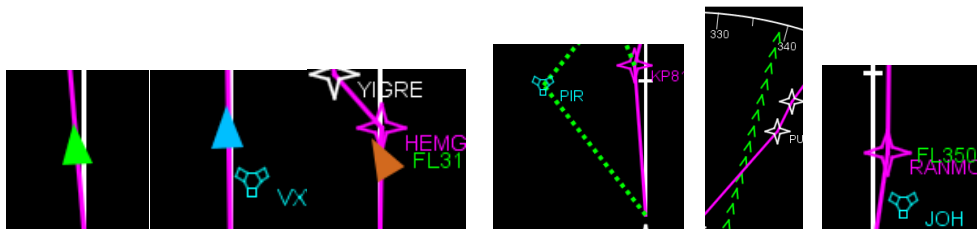
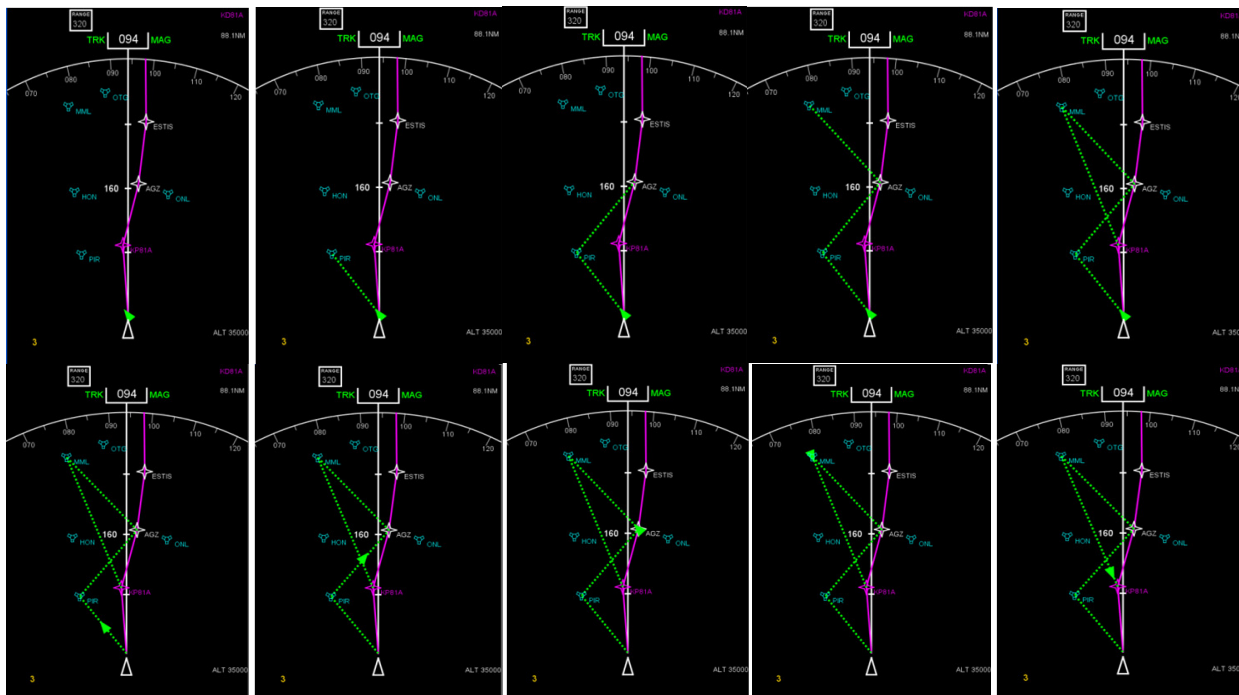
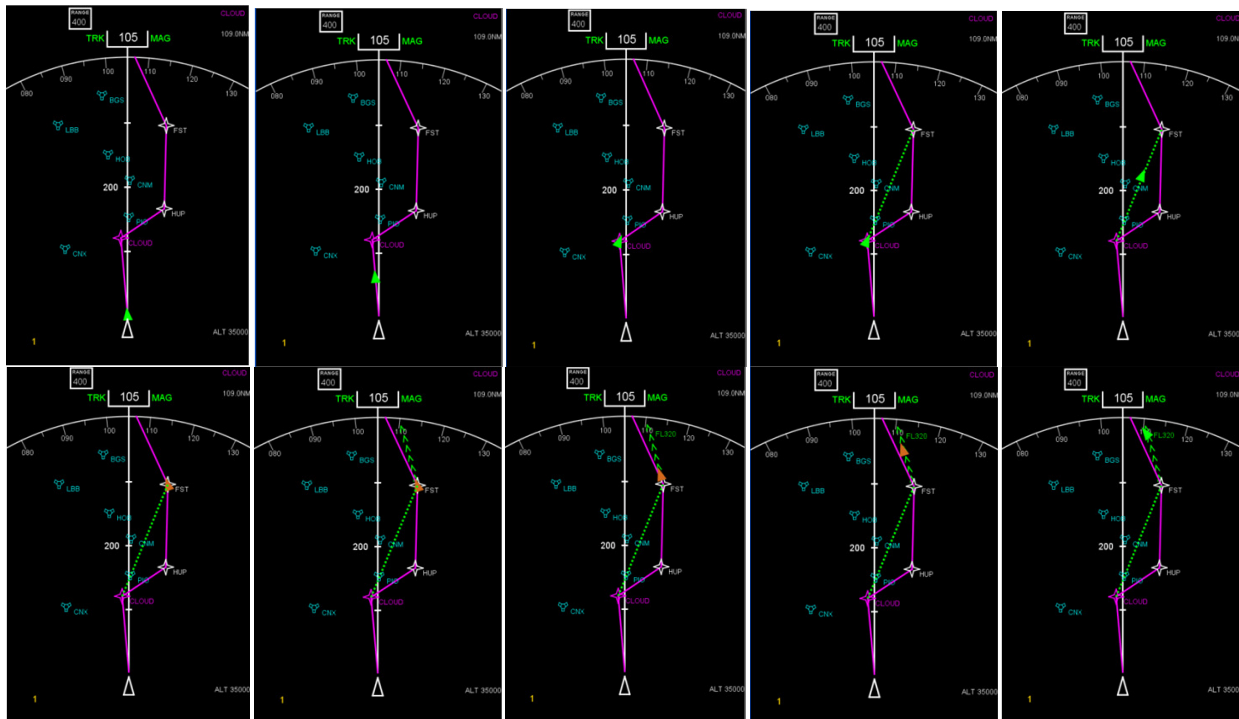


Figure 2. Ownship Symbol (Cruising, Climbing, and Descending), Dotted Line (New Flight Path), Caret Line (New Heading), Text Label (New Objective Altitude)

### Rules of Test Animation

- The triangular ownship symbol moved over the new route. The new route could include part of the original route. All the composed clearances had sequential scenarios, but some clearances included simultaneous scenarios (e.g., "DESCEND TO FL320, FLY HEADING 90" as shown in Figure 1).
- Rather than drawing the entire route clearance as a static graphic first and having the ownship move over the graphics, the route was drawn as discrete steps similar to the way in which the clearance was worded as text. After a portion of the route was drawn, the ownship moved, followed by the drawing of the next part of the route clearance. This continued until the animation was complete. Each part of the reroute graphic remained on the screen after it was drawn. This provided the viewer with a "trail" of the ownship and allowed the pilot to visualize the entire route at the end of the animation.
- The ownship symbol was represented in three different colors depending on the ownship's altitude status. When ownship was requested to climb, the color was sky blue. When ownship was requested to descend, the color was brown. When ownship was instructed to fly at cruising level at an altitude, the color was green. The color code of sky blue and brown was to suggest *sky* and *ground* similar to that used in a primary flight display (PFD). The ownship symbol paused for 0.5 seconds when it arrived at a waypoint or a specified altitude to represent discrete elemental changes as suggested by de Koning et al. (2009) to support relationships between elements and integration.
- The caret line is drawn when the ownship is directed to change heading. The caret lines were drawn from the ownship symbol to the spot on the circumference of the electronic compass in the ND for the angle indication. When the ATC request included a heading change, a caret line was drawn first and the ownship moved over the caret line to indicate that it moved over the path of new heading.
- The text labels of flight level as "FL350" indicated the location where the ownship should meet the altitude.

Figure 3 is an example of steps in an animation with an acceptable clearance scenario. Figure 4 is an example that would be obviously unacceptable.



## Method

Twenty-five civilian pilots (all male) were asked to review the animation concepts. Subjects were briefed on the test system including the flight overview, the ND, the clearance information, and how to play an animation. They were asked to review a minimum of five scenarios. Subjects could ask questions and talk about the concepts as they progressed. Their comments were noted.

After reviewing a minimum of five scenarios pilots were asked their opinions about 1) whether animation would support their ability to correctly interpret the reroute clearances and 2) if animation would help them to rapidly understand the clearance compare to no animation. Subject answers were categorized into three levels 1) positive comment, 2) negative comment, 3) neutral.

## Results

Most pilots were able to give their opinions by reviewing less than 10 scenarios. Figures 5 and 6 present the frequency counts for the three categories for both questions. Results showed that most subjects thought that animation would support the correct interpretation of clearances and support rapid understanding. Subject comments are summarized below.

- The animations would help them understand which portions of the clearance should be completed sequentially versus simultaneous.
- The animation created unnecessary effects that would distract them from desired actions.
- Add the ability to control the animation speed based on user preference. For complex clearances they may want to slow down the animation speed.
- Create a pause function so they can focus on specific regions.
- The subjects indicated that they might miss a color change if the ownship moved over a short segment so recommended changing the line colors to match the different ownship colors. They also suggested changing the color of the text clearance in the same way.
- The animations would be effective as an optional function, because of individual differences in understanding clearances.

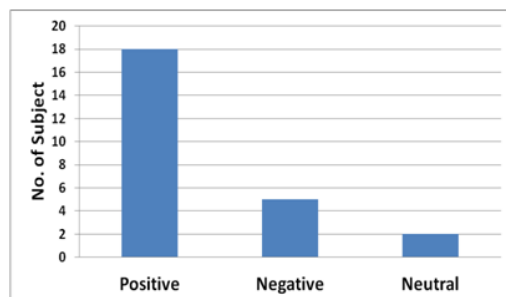


Figure 5. Subjects' Opinion of Animation to Support Correct Interpretation of Clearances

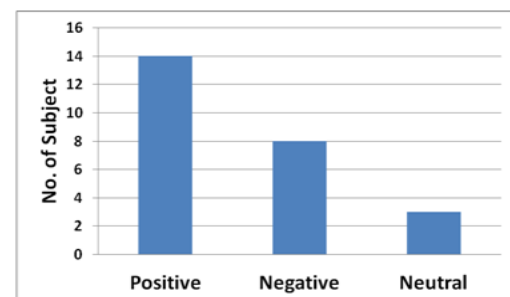


Figure 6. Subjects' Opinion of Animation to Support Rapid Understanding of Clearances

## Discussion

The animated ND display to support understanding of complex text clearances was designed using the principles of attention cueing for animation proposed by de Koning et al (2009) and Amadiou et al. (2011). Most subjects thought that the animations would support rapid and correct understanding of text clearances. This was a first step toward moving to a more detailed design and testing. The drawbacks that pilots mentioned included the difference between their reasoning speed and the speed of the animation. For some, the animation may have been too slow and for others too fast. The speed may need to vary at different times within a complex clearance. If changes are happening simultaneously, the speed may need to be slower, while sequential changes may be presented at higher speed. Subjects' design recommendation of adding an animation speed control is consistent with the implications by Stasko (1993), Ayres and Paas (2007), and Hegarty (2011). To determine appropriate speed ranges additional research is needed. The pilots could then choose from a level of "best" ranges based on their preferences.

Using animation on the ND would require pilots to attend to the display for the period of time that the animation played. Given the need for pilots to multitask this may not be feasible for one-seat cockpits. However, the ability to replay an animation as often as needed may support the pilot so that they can review when they choose. They may also choose animation for specific situations, for example when the clearance is considerably complex or to support one area of the clearance that is not quite understood.

It is recommended that animation always be optional for pilots. However, there is a need for an in-depth study to determine recommended design parameters. The next step would be to evaluate pilot performance using objective measures of accuracy and time to respond to help select the design parameters. These data could be compared to the recent time and accuracy data for presenting text and graphic DataComm clearances by Gallimore et al. (2013).

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